Art. XIX. -The Production of the Tides, Mechanically Considered.

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Let us suppose the earth to be composed of grains of sand, all separate, not one grain in actual contact with another. Let us further suppose, for a moment only, that the force which draws them, as is supposed, towards the moon, acts equally on every particle-on every grain of sand. In this case the earth will keep its form, whatever form it may have.

Now let us take, in part, the actual case. The grains of sand composing the earth on the side nearest the moon are drawn by a greater force than are the grains composing the earth on the side farthest from the moon. This force-the gravitative force of the moon on the earth-varies inversely as the square of the distance from the moon's centre, supposing the moon to be a perfect sphere, and knowing that the attractive force of the moon may be considered as concentrated at the moon's centre. I only wish here to deal with the principle of the moon's action in producing the tides, or rather one of the principles. I have been unable to find any work in Wellington which treats of the Dynamical Theory of the Tides, or of anything relating to it, except what is contained in Newcomb's " Popular Astronomy," and I wish here, therefore, to keep to the direct action of the moon, as it is generally understood.

Let us consider the action of the moon on three portions of the earth:-(a) the portion nearest the moon; (b) the portion in the centre of the earth; and (c) the portion of the earth farthest from the moon. The first portion $(a)$ is drawn by a greater force than the second-the central portion (b), and it therefore bulges towards the moon. The second portion (b) is drawn by a greater force than is the third portion (c), and this last portion, therefore, is left a little behind, and bulges away from the moon. These two bulgent portions are the two tides. The force producing these two tides is measured by the difference of the accelerations
produced by the moon in the respective portions of the earth considered- $a, b$, and $c$.

The total mass of the moon is about one-eightieth of that of the earth, and her mean distance about 240,000 miles (Newcomb). The moon is thus distant about 60 semidiameters of the earth. Whatever may be the earth's attractive force on a small mass at its surface, the moon's attractive force is $\frac{1}{80}$ th of $\frac{1}{60}$ th of $\frac{1}{60}$ th of this force-the earth's attractive force. The tide-produciny force of the moon (in part) is, however, only as the difference between $\frac{1}{80}$ th of $\frac{1}{59}$ th of $\frac{1}{59}$ th and $\frac{1}{80}$ th of $\frac{1}{61}$ st of $\frac{1}{61}$ st of the earth's attractive force on a small mass at its surface. The calculation is too tedious to go through, and it is only required to have some idea of the magnitude. It will suffice here, therefore, to say that the tide-producing power of the moon is very much less than a millionth of the power of the earth to draw a small mass at its surface towards its centre.

The tide-producing force of the moon being so small compared to the power of the earth to draw a mass at its surface towards its centre, how can it possibly pull up from the surface of the earth a portion of its liquid surface? It is impossible for a very small force to lift up a small mass when there is a vast force pulling it down. The moon, however, certainly produces the tides. The only question is, how?

Now, water is slightly compressible, and the pressure of the upper portion of the oceans is very great on the lower portions. If this pressure were weakened, as by the action of the moon, the elasticity of the water would cause the ocean to swell up where the pressure was relieved. If my memory serves me rightly, Mr. Murray, of the "Challenger Exploring Expedition," in a lecture at Edinburgh, estimated that if the force of gravity of the earth were to be suspended, the waters of the ocean would swell up, raising the waterlevel over the earth by 500 feet. Now the tide-producing power of the moon reduces the force of gravity of the earth, and thus relieves the pressure of the water of the ocean under the moon. The ocean, owing to the elasticity of the water, swells up, and a tide is produced.

Is the elasticity of the water sufficiently great to produce the actual tide of, say four feet in the open ocean?

The relief of pressure here producible by the moon is less than one-millionth of the pressure produced by the force

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of gravity of the earth acting on the oceans, the tide thus producible would be less, therefore, than one-millionth of 500 feet. This would be a mere ripple on the actual tide.

When the weight of air over any place is greater than the average for that place at that time of the year, it produces, if on the ocean, a hollow in its surface, and of course there must be a corresponding rise around this hollow. Now, the moon weakens the force of gravity of the earth under the moon (and on the opposite side of the earth also), and the weight or pressure of water under the moon is less than the weight or pressure of water at places on the earth (oceanic regions) at right angles to a line drawn from the moon's centre to the earth's centre. The greater pressure of water at places a great distance from the vertical moon will therefore cause a hollow there and a rise, wave, or tide under the moon, that is, if the action of the moon could immediately produce its full effect. Time must, however, be allowed to overcome the inertia of the water. The rise, or tidal wave of water therefore follows some time after the vertical moon.

The reasoning in this paper therefore shows :-First, that it is impossible for the slight attractive force of the moon to lift up a body of water directly against the vastly greater force of gravity of the earth drawing this water down. Second, that it is the greater weight of water at a great distance from the moon's vertical, so to speak, that makes a hollow there, and a corresponding rise nearer the moon's vertical.

